

CORROSION RESISTANCE OF DOWEL BARS
(ORGANIC COATINGS)

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MICHIGAN DEPARTMENT OF
STATE HIGHWAYS AND TRANSPORTATION

CORROSION RESISTANCE OF DOWEL BARS
(ORGANIC COATINGS)

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Introduction

This project was started in 1952. The dowel coatings under evaluation then were quite diverse, ranging from stainless steel and Monel sleeves, chromium and nickel platings, and galvanizing, to rust inhibitive paints at standard thickness. For one reason or another, none of these coatings was used extensively on a national scale. However, the need for better performance of load transfer devices in roadway joints persisted.

In early 1971, AASHO-ARBA Task Force No. 8, under encouragement of the FHWA, was created to study so-called low cost dowel coatings that had become available, such as extruded polyethylene and powder epoxies. The current phase of the Laboratory's research covers evaluation of some of the coatings, approved in the AASHO-ARBA study, and a few other suggested coatings.

Reports No. R-497 and 591 cover the Laboratory's prior evaluations of coated dowel bars in laboratory and field tests.

Five sets of 1-1/4 by 18-in. (Standard MDSH size) coated dowel bars, having laboratory identification numbers, composition, and source as indicated, were obtained for test purposes:

- 72 M-48 - Extruded polyethylene - Republic Steel
- 72 M-50 - Epoxy powder; "Dowel clad" Cook Paint and Varnish Co. - U.S. Steel
- 72 M-53 - Nylon modified polyamide cured epoxy; "Uni Pace" - Garlock Inc. of Austin, Texas
- 73 M-3 - Epoxy powder; "Scotchkote 202" - 3M Co.
- 73 M-4 - Urethane elastomer; "Adiprene" - DuPont Co.

Proposed AASHO Specifications for Corrosion Resistant Dowels transmitted November 17, 1972 list three tests to determine the suitability of such coatings for use in load-transfer device service.

The specified tests are:

- 1) Corrosion Pull-Out Tests
- 2) Corrosion-Abrasion Tests
- 3) Deflection Tests

Accordingly laboratory testing of the five coated dowel systems was done in accordance with AASHO specified tests when possible.

TABLE 1
CORROSION PULL-OUT TESTS

Coating	Thickness, mils	24-hr Bond Strength				Bond Strength After 50 Freeze-Thaw Cycles			
		With RC-250 lubricant ¹ (2 dowels tested)		Without lubricant (1 dowel tested)		With RC-250 lubricant ¹ (2 dowels tested)		Without lubricant (1 dowel tested)	
		Load, lb	psi	Load, lb	psi	Load, lb	psi	Load, lb	psi
Extruded polyethylene (72 M-48) ²	20		400 ³	19-21		466 ³	22		
Epoxy powder (72 M-50)	10	52	2-3	4,300	182	67	2-3	4,775	202 ⁴
Nylon modified epoxy (72 M-53)	6	41	2	3,700	157	74	3	5,100 ⁵	216
Epoxy powder (73 M-3)	11	34	1-2	1,900	81	59	2-3	3,725	158
Urethane elastomer (73 M-4)	10	105	3-6	3,900	165 ⁶	177	7-8	1,175 ⁷	50

¹RC-250 is a cut-back asphalt applied 2-3 mils thick.

²Dowels were 1-1/8-in. diameter instead of 1-1/4 in. diameter. Two dowels were tested.

³It was noted that movement occurred at the steel-plastic interface and not the concrete-plastic contact.

⁴Three days in moist room instead of 14.

⁵Coating scuffed off bar when pulled.

⁶Test run 72 hours after removing from mold.

⁷Block cracked, relieving pressure on dowel bar.

1) Corrosion Pull-Out Tests

The corrosion pull-out test was followed in detail except that in the freeze-thaw exposure, the complete block assembly was immersed in the calcium chloride solution to the level of the dowel axis. Detailed testing procedure is given in the Appendix.

Table 1 shows the bond strength of the coated dowels, lubricated and unlubricated, before and after 50 freeze-thaw cycles.

A review of the data shows: a) that all the 24-hour bond strengths on the unlubricated dowels exceed the AASHTO suggested maximum load of 1,272 lb (60 psi) except for the extruded polyethylene coating which is about 1/3 of the latter; b) that on the non-plastic coatings the 24-hour bond strengths are fairly uniform except for the 1,900 lb load on one epoxy coating, suggesting that surface smoothness and a near cylindrical shape can lower the pull-out value significantly; c) applying the test lubricants to the dowels lowers the pull-out load by more than a factor of 30 for both the 24-hour and longer bond strengths; and, d) the pull-out loads on the test coated dowels increased modestly by 10 percent, or slightly more, during the 50 freeze-thaw cycles. The latter was attributed primarily to shrinkage of the concrete during aging since there was no failure of any of the test coatings during the 50 freeze-thaw cycle exposure. Figure 1 shows a typical cut-away of encasing concrete, with no indication of rust staining.

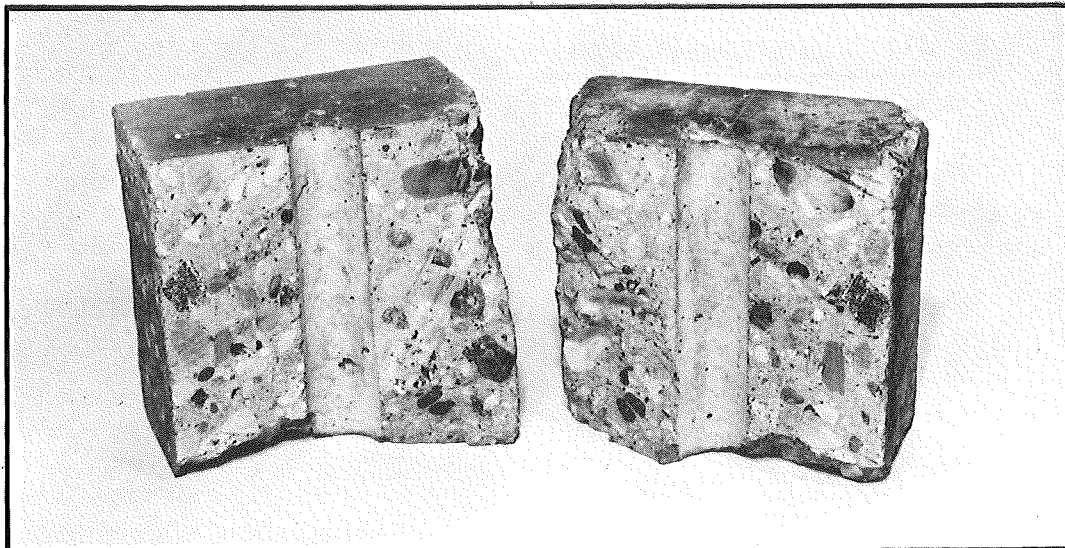


Figure 1. Broken concrete block from powder epoxy coated dowel (73 M-3) showing absence of corrosion stain in dowel cavity after 50 freeze-thaw cycles. Typical for all coatings tested.

2) Corrosion-Abrasion Tests

Previous experience with the AASHO specified abrasion tester has determined that this procedure, though simulating actual conditions, is too difficult to run meaningfully.

Other ways of determining the abrasion resistance of coatings, such as a Limestone Drop Test (ASTM G 14-69T) and an Aluminum Oxide Slurry Test (ASTM G 6-69T) were rejected in favor of an improvised sandblast test. This test was consistent and worked well on the hard coatings.

In this test method, we directed a stream of sand at a spot on the coated dowel bar, normal to the dowel, using a 3/16-in. opening blasting nozzle, held 1-3/4-in. from the dowel surface. New silica sand was used under a pressure of 100 psi. Results were computed on the basis of time of penetration per mil of coating as given in Table 2.

TABLE 2
ABRASION RESISTANCE (SANDBLAST) OF COATINGS

Sample	Type of Coating	Thickness, mils	Time, seconds/ mil of coating
72 M-48	Extruded polyethylene	20	10.6*
72 M-50	Epoxy powder	10	10.9
72 M-53	Nylon modified epoxy	6	1.2
73 M-3	Epoxy powder	11	13.4
73 M-4	Urethane elastomer	11	27.5

*Coating melted just before failure.

The extruded polyethylene should normally be very resistant to abrasion, however the heat generated by the bombardment of the sand softened the plastic enough to allow penetration in the indicated time.

As indicated in the Table, the two epoxy powder coatings had almost identical penetration times with the urethane elastomer having the best sand blast resistance. The nylon modified epoxy had very poor resistance to the sandblast stream.

3) Deflection Tests

To save time on the screening tests, the AASHO designated deflection tests were not conducted since it was felt that all dowels would pass the test as they were of the same steel and the coatings were not excessively thick or inordinately soft.

Mar Resistance Tests

In order to determine the comparative resistance to coating damage in the handling and storage of coated dowels, a test described in ASTM A-123-- a specification for zinc (hot galvanized) coatings on steel products--was made on the five coating systems being evaluated for dowel bars.

Figure 2 shows the testing equipment as adapted to the testing of coated dowels with the hammer blow normal to the surface and the chisel end aligned longitudinally with the dowel. The dowel is rotated 1/8 in. between blows.

Since dowels in transit are exposed to a temperature range, tests were run at 75 and 40 F.

The test results indicate that the epoxy powder coatings have good mar resistance at normal temperatures. The resistance decreases at lower temperatures as could be expected (Table 3).

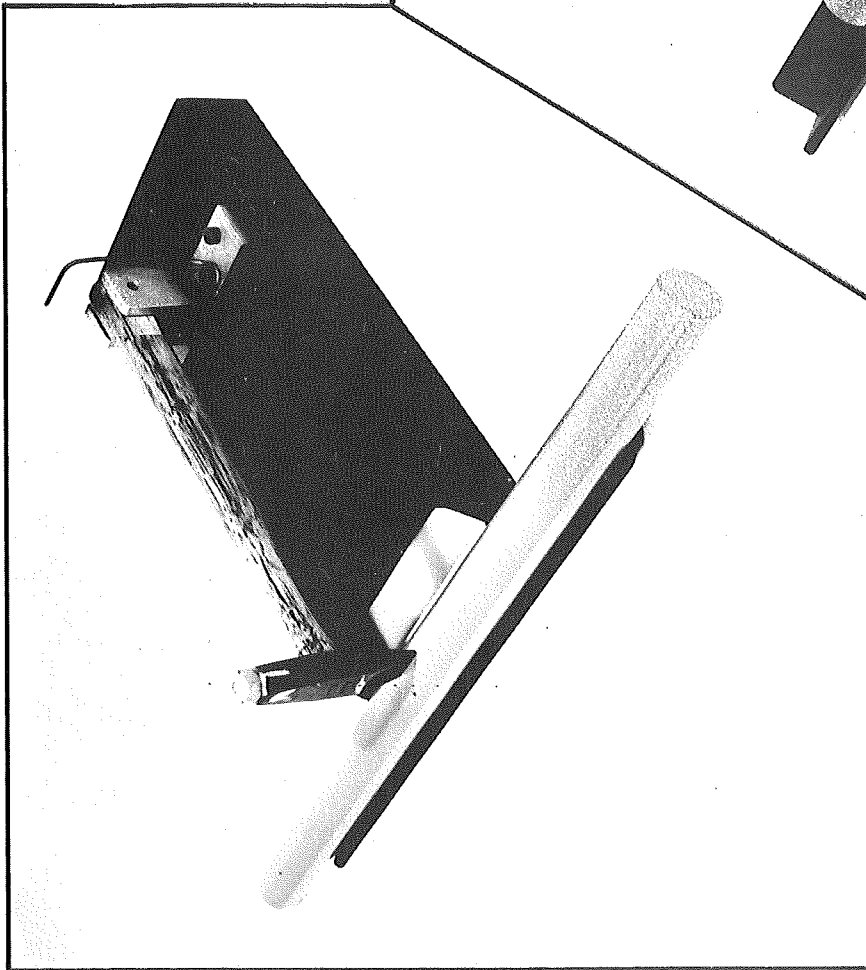
TABLE 3
MAR RESISTANCE OF COATINGS (RIVET HAMMER)

Coating	Thickness, mils	Temperature 75 F		Temperature 40 F	
		Penetration (to steel)	Coating Flake-Off	Penetration (to steel)	Coating Flake-Off
Extruded polyethylene (72 M-48)	20	Yes	No	Yes	No
Epoxy powder (72 M-50)	10	No	No	Yes	Yes
Nylon modified epoxy (72 M-53)	6	Yes	Yes	Yes	Yes
Epoxy powder (73 M-3)	11	No	No	Yes	Yes
Urethane elastomer (73 M-4)	10	No	Yes *	No	Yes *

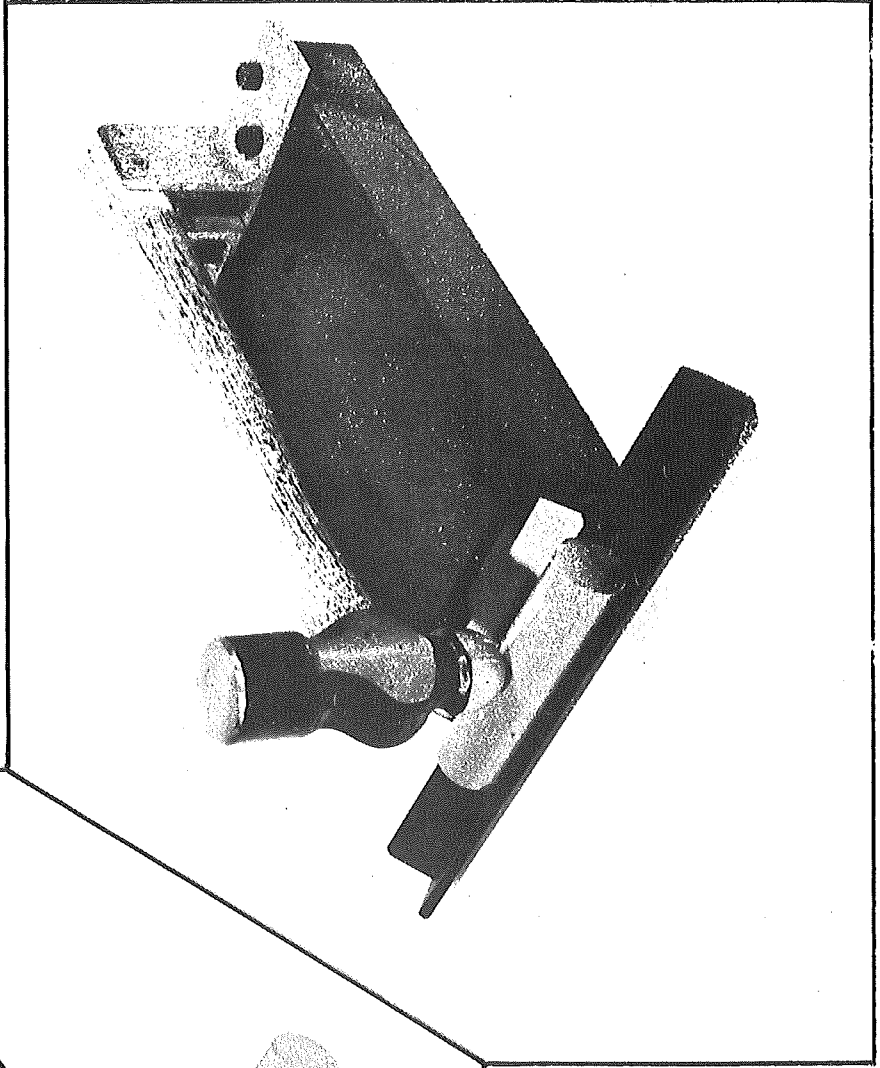
*Off primer

The nylon modified epoxy has the somewhat poorest mar resistance, which is due primarily to its brittleness.

In another similar test to evaluate the mar resistance of the coatings, a modified version of ASTM G 14-69T was used. Essentially the test consisted of having a 3-lb ball-peen hammer pivot-mounted and adjusted to strike a coated dowel bar normal to its surface as shown in Figure 3. The impact testing results run at 75 and 40 F are listed in Table 4.



▲ Figure 2. Pivoted rivet hammer used for testing mar resistance of coated dowels.



▲ Figure 3. Pivoted ball-peen hammer used for testing mar resistance of coated dowels.

TABLE 4
MAR RESISTANCE OF COATINGS (BALL-PEEN HAMMER)

Coating	Thickness, mils	Temperature 75 F		Temperature 40 F	
		Penetration (to steel)	Coating Flake-Off	Penetration (to steel)	Coating Flake-Off
Extruded polyethylene (72 M-48)	20	Yes	No	Yes	No
Epoxy powder (72 M-50)	10	No	No	Yes	Yes
Nylon modified epoxy (72 M-53)	6	Yes	Yes	Yes	Yes
Epoxy powder (73 M-3)	11	No	No	No	No
Urethane elastomer (73 M-4)	10	No	Yes*	Yes	Yes*

*Off primer

In general, the extruded polyethylene and powdered epoxies gave indications of good mar resistance. The urethane elastomers tended to be soft enough to sustain damage from hard blows. The nylon modified epoxy was very brittle and would be easily damaged.

Conclusions and Recommendations

1) This report presents data from improvised laboratory screening tests conducted on five dowel coating systems. The data show marginal differences in behavior of the coatings under test conditions. On the basis of the data, we rate the coatings accordingly:

- a) 72 M-48 - Extruded polyethylene
- b-1) 73 M-3 - Powdered epoxy
- b-2) 73 M-4 - Urethane elastomer
- c) 72 M-50 - Powdered epoxy
- d) 72 M-53 - Nylon modified epoxy

The 72 M-50 epoxy is rated lower than the 73 M-3 epoxy because of its poorer mar resistance at low temperatures (Table 4). The 72 M-53 nylon modified epoxy is rated lower than the others because of poorest abrasion and mar resistances.

It was noted in the screening tests that the extruded polyethylene coating slipped at the plastic-dowel interface during pull-out tests. This might lead to wrinkling and eventual fracture of the coating during service exposure even though there is some tendency of the strained plastic to flow back to its original length.

2) To obtain actual data on the handling and performance of subject coated dowels, we recommend that the better ones be scheduled for service exposure.

a) For service exposure we recommend that coating thickness be maintained as evaluated in subject screening tests, i.e., about 20 mils for the polyethylene coatings and about 10 mils for the other coatings.

b) To assure less than the recommended 60 psi maximum pull-out on the coated dowels in service exposure all would have to be coated with a bond-breaking lubricant except for the extruded polyethylene.

APPENDIX

Preparation and Testing Details for Corrosion Pull-Out Specimens

Three coated dowels from each of the five types to be tested were saw cut to a length of 12-3/4 in. This number provided two bars for use with a lubricant¹ and one without, which could be made into test specimens in three molds with one concrete mix.

The dowels were fitted into the molds by means of 6 by 6-1/4 by 1/4-in. end plates with center holes the diameter of the dowel bar. A center plate of the same size was split to allow removal after the specimen was cast. All plates were held in a vertical position by sliding them into 1/8-in. vertical slots milled into the sides of the mold.

Test specimens were cast using concrete containing 6 sacks of cement per cu yd and the amount of aggregate shown in Table 6 of ACI Recommended Practice 613-54. The concrete was consolidated in the molds by means of an external vibrator. Slump of the various mixes ran from 1-1/2 to 3 in. and air content 4.1 to 5.8 percent. Average compressive strength of the concrete was 5,100 psi.

Specimens were removed from the molds 24 hours after forming. Using an Instron Universal testing machine, the tensile stress was measured at a strain rate of 0.02 in. per minute until a space of 1/2 in. between the two concrete sections was obtained. The maximum pulling load in pounds was recorded.

The specimens were put into moist storage and allowed to cure for 14 days and then allowed to dry at 75 F for 14 days. Specimens were then put into water up to the level of the dowel bar axis². After 24 hours the water was replaced with a 4 percent (by weight) calcium chloride solution.

Specimens were then subjected to 50 cycles of 16 hours freeze and 8 hours thaw. Over weekends the freeze cycle was extended to 64 hours.

After cycling, the maximum amount of pull needed to remove the dowel from a block was determined.

¹ The extruded polyethylene coated bars were not lubricated.

² This was an alteration of the AASHO specified procedure using a dam in joint space. New York State is specifying a similar procedure. After completion of the tests, no deterioration of the bottoms of the concrete blocks was noted, which could be ascribed to this alteration.